(12) UK Patent Application (19) GB (11) 2 386 475 (13) A

(43) Date of A Publication 17.09.2003

(21) Application No 0205739.6

(22) Date of Filing 12.03.2002

(71) Applicant(s)
antenova Limited
(Incorporated in the United Kingdom)
Far Field House, Bury Farm,
Stoke-cum-Quy, CAMBRIDGE, CB5 9AR,
United Kingdom

(72) Inventor(s)
Simon Philip Kingsley
Scott William Spencer Tyler

(74) Agent and/or Address for Service
Harrison Goddard Foote
Belgrave Hall, Belgrave Street, LEEDS,
LS2 8DD, United Kingdom

(51) INT CL^7
H01Q 9/04

(52) UK CL (Edition V)
H1Q QDX

(56) Documents Cited
WO 2001/069721 A1

(58) Field of Search
INT CL^7 H01Q
Other: Online: WPI, PAJ, INSPEC, EPODOC

(54) Abstract Title
Multi-element dielectric resonator antenna

(57) An antenna device (14) comprises a pair or more (eg. four), of dielectric resonator antenna elements (1, 1'), each element (1, 1') comprising a dielectric resonator provided with a feed (4, 6, 7) and a conductive backwall (3). One element is configured as a transmit antenna (1) and the other as a receive antenna (1'). The elements (1, 1') are positioned with their conductive backwalls (3) directly facing each other and substantially parallel. Several such antenna devices (14) may be formed as an array, with side-wise adjacent devices (14) having an orientation of the transmit and receive elements (1, 1') reversed, thereby giving near omnidirectional coverage with much reduced coupling between transmit (1) and receive (1') elements. Metal walls between the elements can reduce coupling (fig 6).

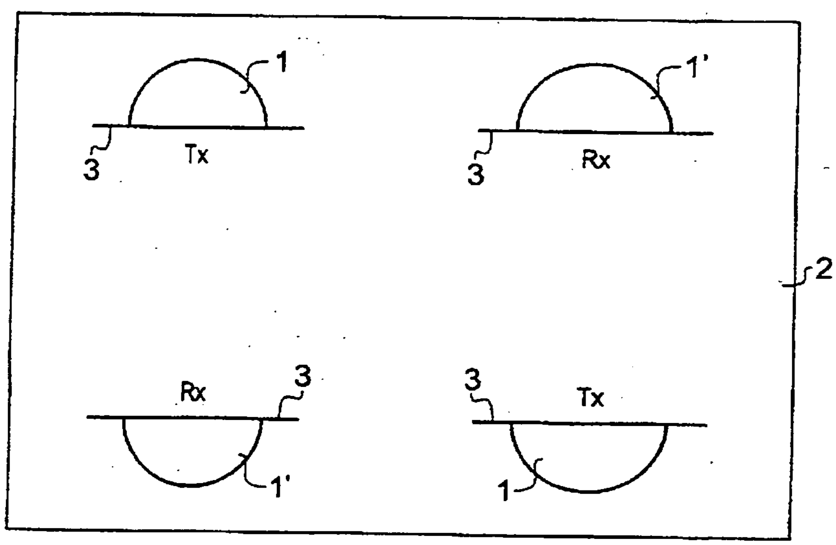

Fig. 5

GB 2 386 475

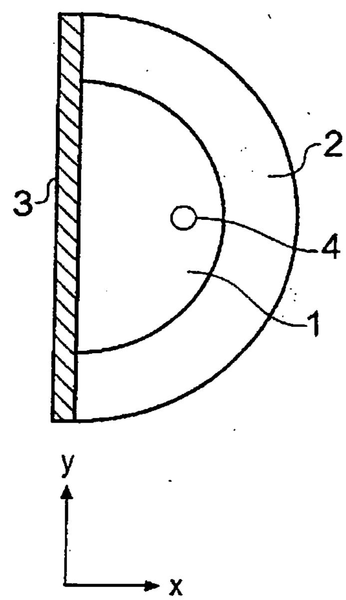

Fig. 1

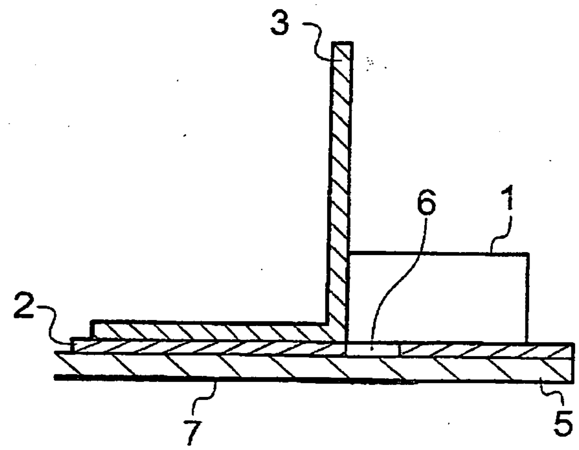

Fig. 2

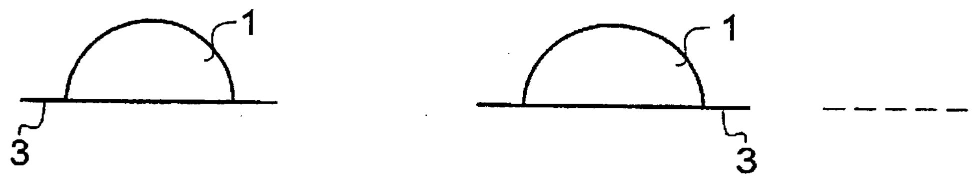

Fig. 3

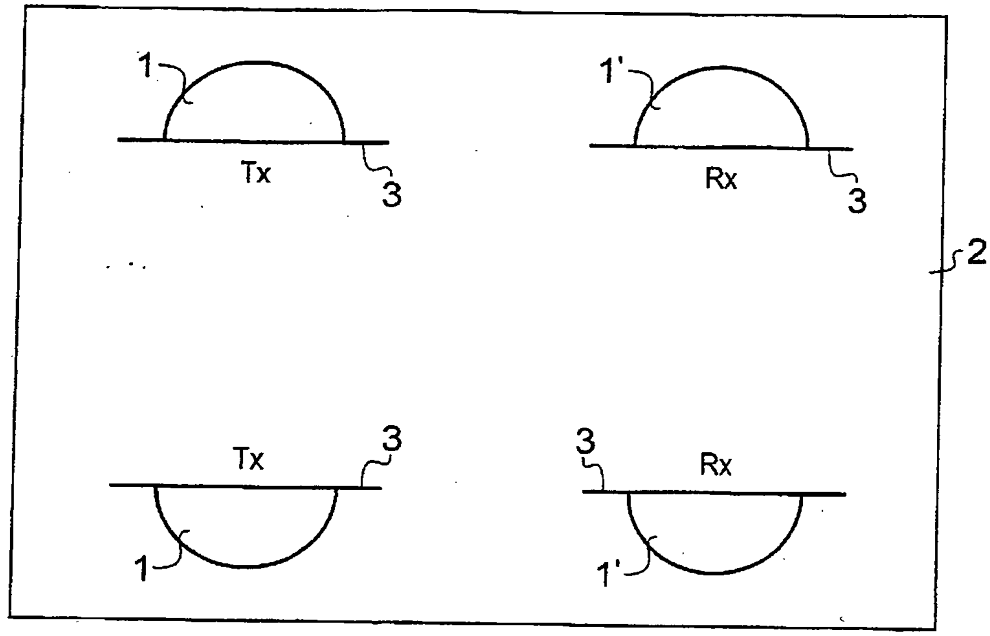

Fig. 4

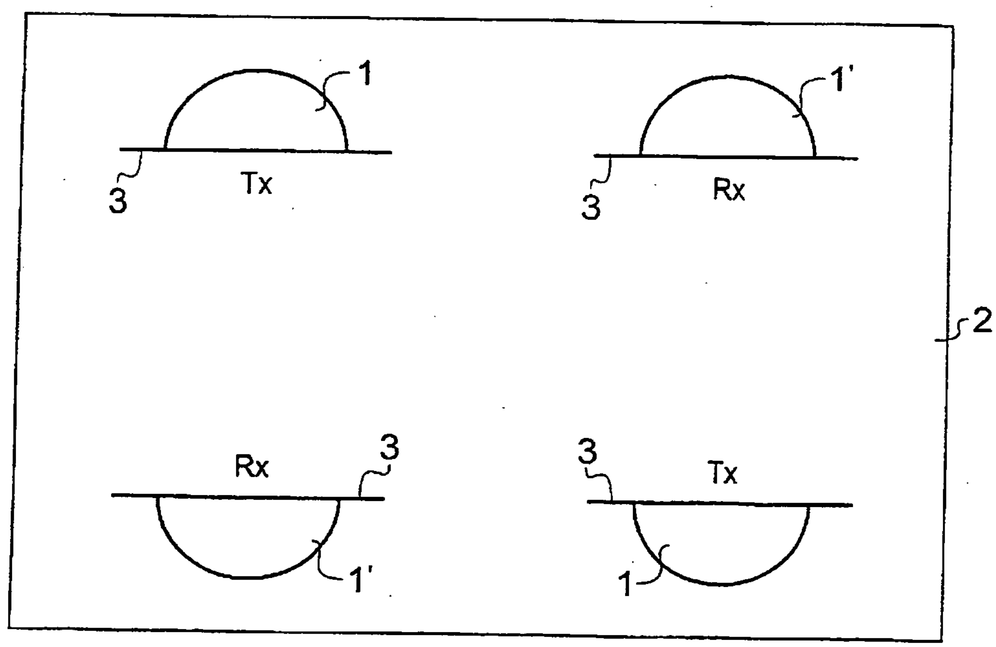

Fig. 5

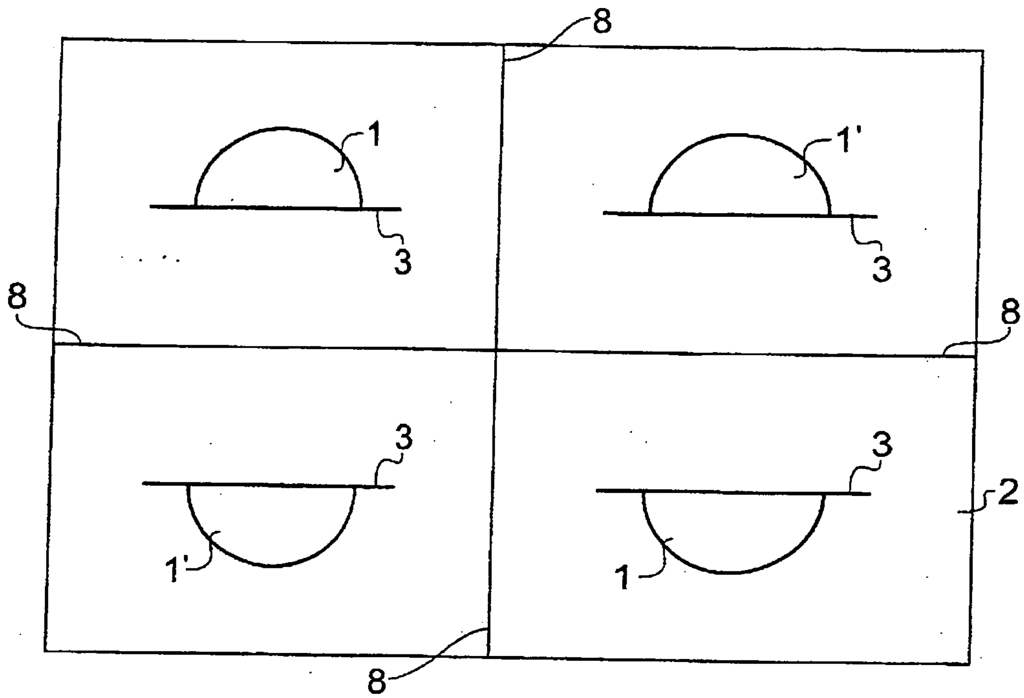

Fig. 6

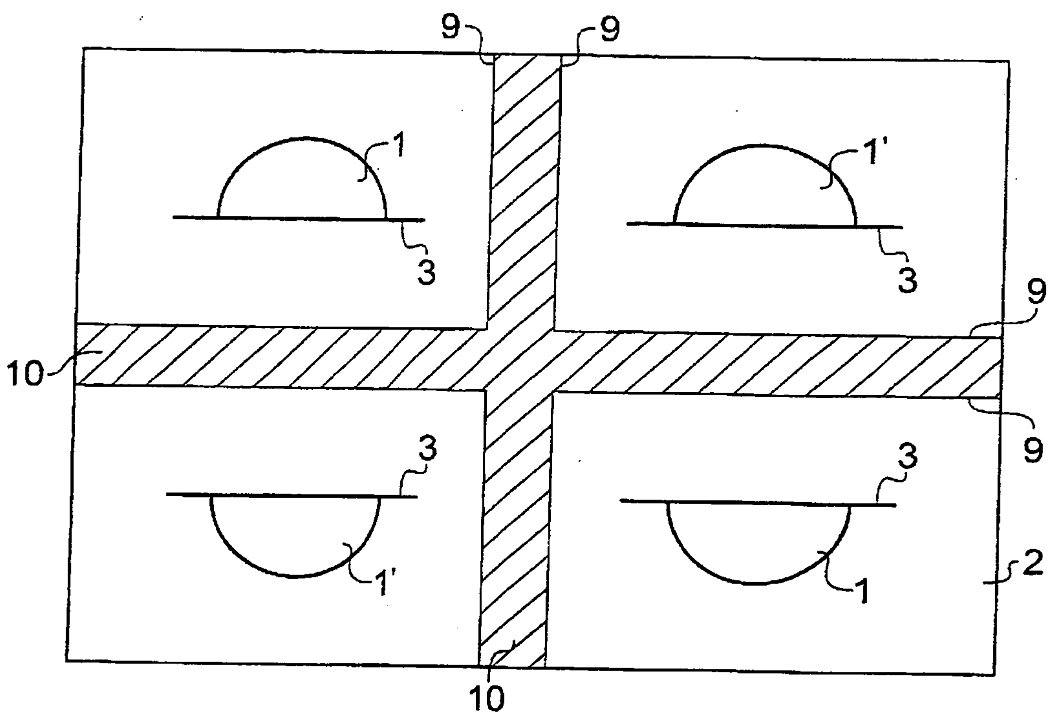

Fig. 7

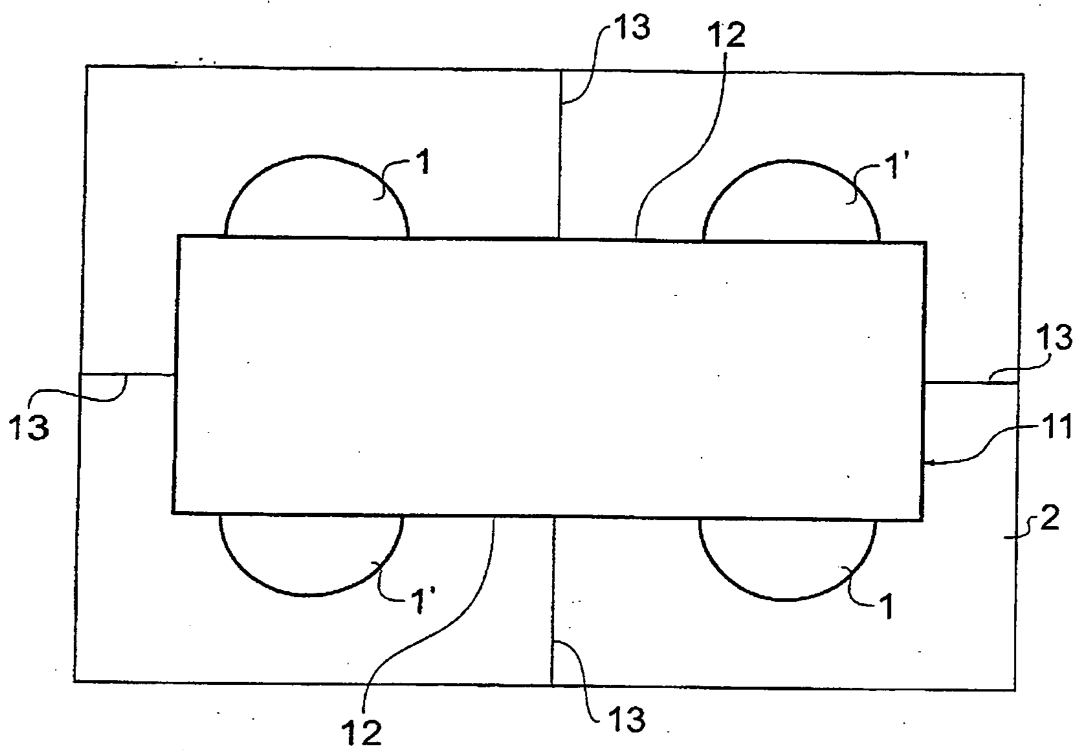

Fig. 8

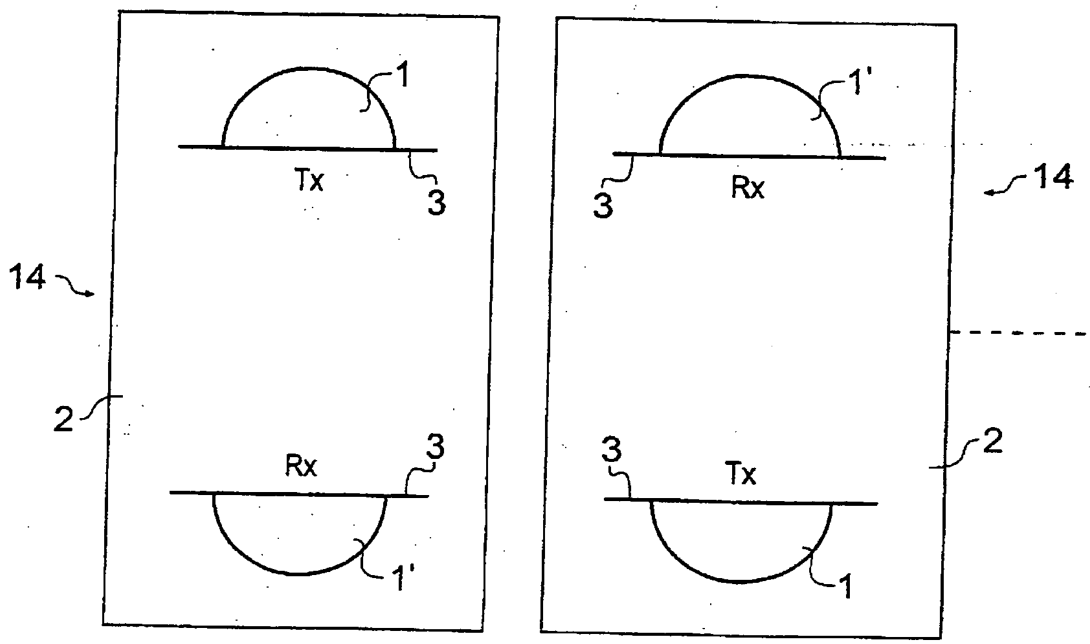

Fig. 9

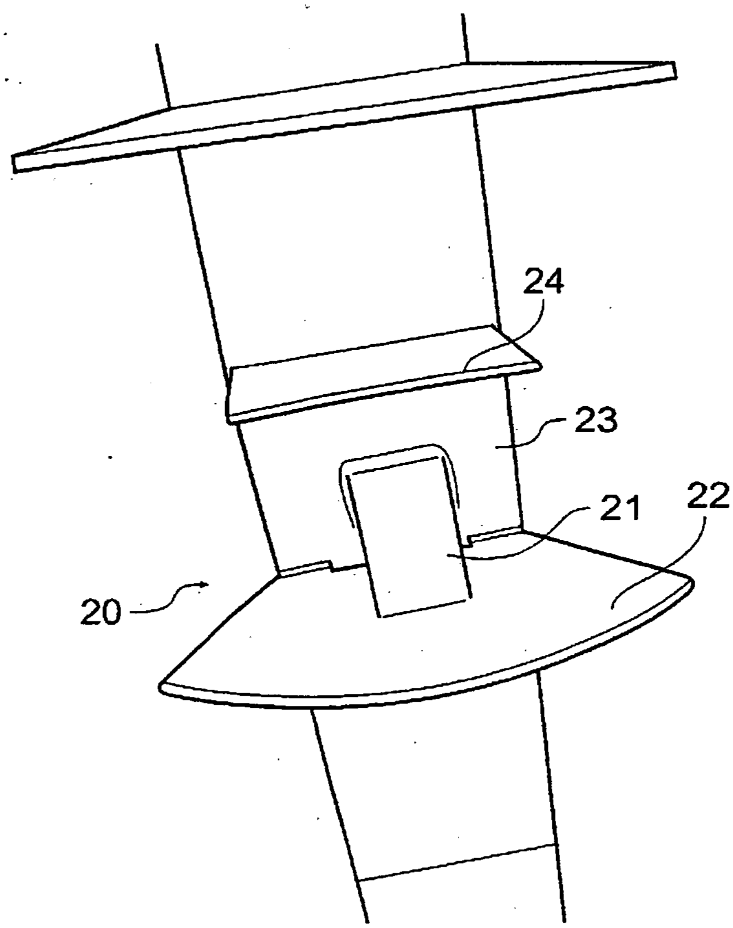

Fig. 10

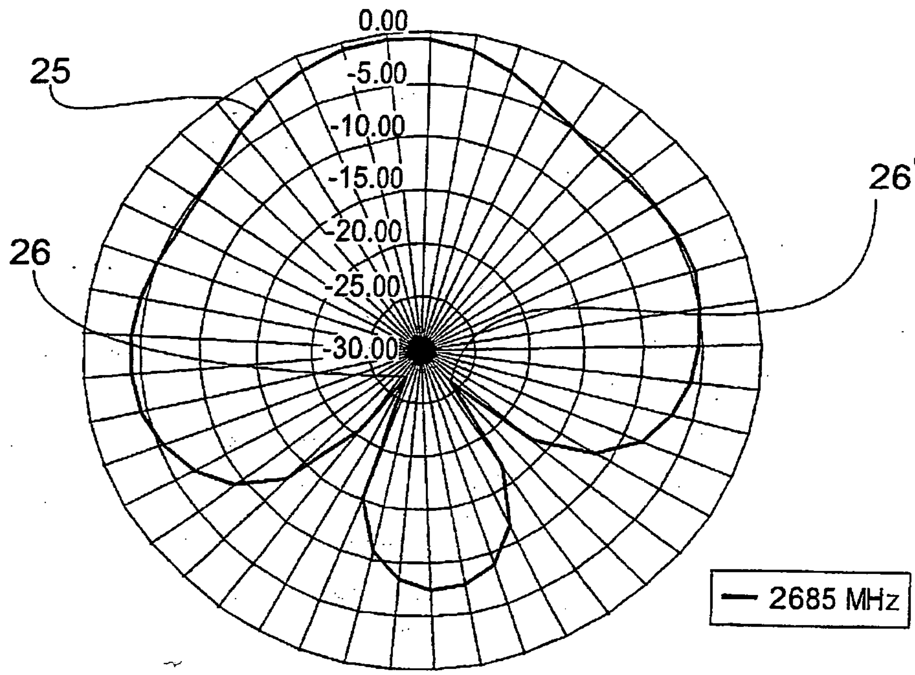
0.00
-5.00
-10.00
-15.00
-20.00
-25.00
-30.00
25
26
26'
2685 MHz

Fig. 11

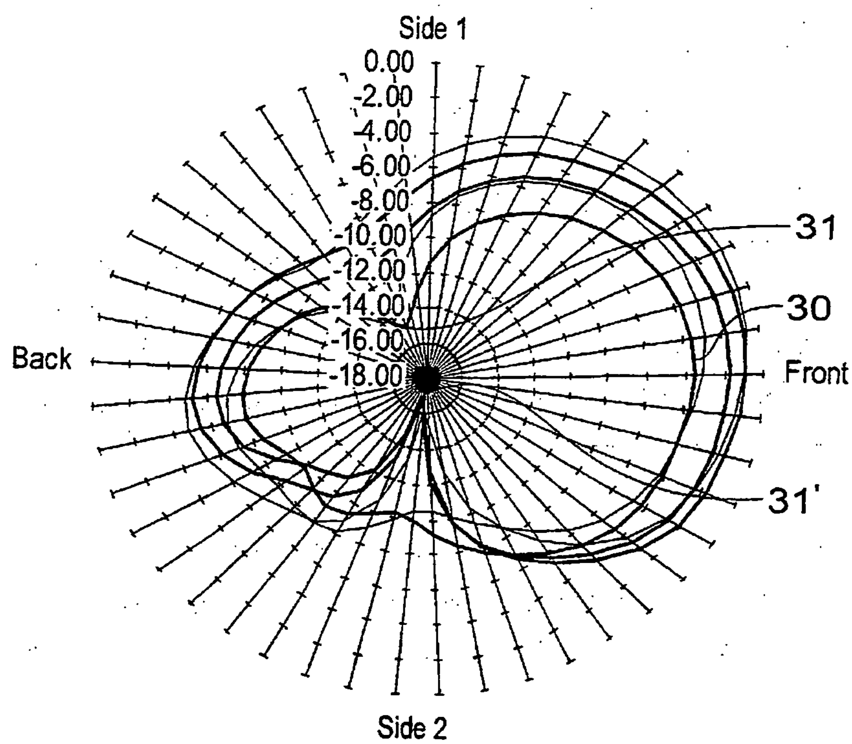
Side 1
0.00
-2.00
-4.00
-6.00
-8.00
-10.00
-12.00
-14.00
-16.00
-18.00
Back
Front
31
30
31'
Side 2

Fig. 12

2386475

DIELECTRIC RESONATOR ANTENNA WITH TRANSMITTING AND RECEIVING ELEMENTS

The present invention relates to a dielectric resonator antenna with transmitting and receiving elements, and also to arrays of such antennas.

Since the first systematic study of dielectric resonator antennas (DRAs) in 1983 [LONG, S.A., McALLISTER, M.W., and SHEN, L.C.: "The Resonant Cylindrical Dielectric Cavity Antenna", IEEE Transactions on Antennas and Propagation, AP-31, 1983, pp 406-412], interest has grown in their radiation patterns because of their high radiation efficiency, good match to most commonly used transmission lines and small physical size [MONGIA, R.K. and BHARTIA, P.: "Dielectric Resonator Antennas - A Review and General Design Relations for Resonant Frequency and Bandwidth", International Journal of Microwave and Millimetre-Wave Computer-Aided Engineering, 1994, 4, (3), pp 230-247].

The majority of configurations reported to date have used a slab of dielectric material mounted on a ground plane excited by either an single aperture feed in the ground plane [ITTIPIBOON, A., MONGIA, R.K., ANTAR, Y.M.M., BHARTIA, P. and CUHACI, M: "Aperture Fed Rectangular and Triangular Dielectric Resonators for use as Magnetic Dipole Antennas", Electronics Letters, 1993, 29, (23), pp 2001-2002] or by a single probe inserted into the dielectric material [McALLISTER, M.W., LONG, S.A. and CONWAY G.L.: "Rectangular Dielectric Resonator Antenna", Electronics Letters, 1983, 19, (6), pp 218-219]. Direct excitation by a transmission line has also been reported by some authors [KRANENBURG, R.A. and LONG, S.A.: "Microstrip Transmission Line Excitation of Dielectric Resonator Antennas", Electronics Letters, 1994, 24, (18), pp 1156-1157].

Several authors have already explored the concept of using a series of DRAs to build an antenna array. For example, an array of two cylindrical single-feed DRAs has been demonstrated [CHOW, K.Y., LEUNG, K.W., LUK, K.M. AND YUNG,

E.K.N.: "Cylindrical dielectric resonator antenna array", Electronics Letters, 1995, 31, (18), pp 1536-1537] and then extended to a square matrix of four DRAs [LEUNG, K.W., LO, H.Y., LUK, K.M. AND YUNG, E.K.N.: "Two-dimensional cylindrical dielectric resonator antenna array", Electronics Letters, 1998, 34, (13), pp 1283-1285]. A square matrix of four cross DRAs has also been investigated [PETOSA, A., ITTIPIBOON, A. AND CUHACI, M.: "Array of circular-polarized cross dielectric resonator antennas", Electronics Letters, 1996, 32, (19), pp 1742-1743]. Long linear arrays of single-feed DRAs have also been investigated with feeding by either a dielectric waveguide [BIRAND, M.T. AND GELSTHORPE, R.V.: "Experimental millimetric array using dielectric radiators fed by means of dielectric waveguide", Electronics Letters, 1983, 17, (18), pp 633-635] or a microstrip [PETOSA, A., MONGIA, R.K., ITTIPIBOON, A. AND WIGHT, J.S.: "Design of microstrip-fed series array of dielectric resonator antennas", Electronics Letters, 1995, 31, (16), pp 1306-1307]. This last research group has also found a method of improving the bandwidth of microstrip-fed DRA arrays [PETOSA, A., ITTIPIBOON, A., CUHACI, M. AND LAROSE, R.: "Bandwidth improvement for microstrip-fed series array of dielectric resonator antennas", Electronics Letters, 1996, 32, (7), pp 608-609]. A study has recently been made of different configurations that can be used to form cylindrical dielectric resonator antenna broadside arrays [WU, Z.; DAVIS, L.E. AND DROSSOS, G.: "Cylindrical dielectric resonator antenna arrays ", Proceedings of the 11th International Conference on Antennas and Propagation, 2001, p. 668.]

A method of disposing array elements in a closely packed arrangement has been disclosed by the present applicant in its copending patent application GB2360133A, the full disclosure of which is hereby incorporated into the present application by reference. That patent application describes a DRA in which the geometry of a circular array of elements as a whole is matched to the geometry of the elements themselves in order to obtain maximum element packing.

In some telecommunications applications, there is a desire for separate but closely spaced transmit and receive antennas as part of an antenna system. Ideally, the transmit and receive antennas should both be vertically polarised, have near omni-directional radiation patterns, but be sufficiently isolated from each other such that transmit-receive switches, diplexers, etc. can be eliminated since these are often large, expensive devices that introduce some insertion loss into the system. However, one must ordinarily expect two such closely spaced antennas to produce near omni-directional patterns which are tightly coupled together, especially when their separation is near to, or less than, a wavelength at the frequency of operation. Furthermore, there is also a strong desire that the two antennas should not be tall, despite the need for vertical polarisation.

An example of where such an antenna system might be required is on top of conventional outdoor telephone boxes that some telecommunications operators are considering licensing as micro- or pico-base station sites. Government planning permission cannot easily be obtained to increase the height of the telephone box, which means that the antenna system must have a low vertical profile. Micro- or pico-base station equipment inside the telephone box should be as small and as inexpensive as possible. It is preferred to avoid using a diplexer, so requiring separate transmit and receive antennas having low mutual coupling (otherwise the transmit power could get into the receiver at sufficiently high levels to cause damage).

Embodiments of the present invention seek to provide an antenna arrangement that attempts to meet these difficult and apparently contradictory requirements. The technology is particularly applicable to GSM, CDMA and 3G base stations which transmit and receive simultaneously and where isolation, or cross-talk, between the transmit and receive antennas must be kept as low as possible.

It has been known for some time that a cylindrical DRA operating in the $HEM_{11\delta}$ mode is an effective radiating device [MONGIA, R.K. and BHARTIA, P.:

"Dielectric Resonator Antennas - A Review and General Design Relations for Resonant Frequency and Bandwidth", International Journal of Microwave and Millimetre-Wave Computer-Aided Engineering, 1994, 4, (3), pp 230-247]. An examination of the electromagnetic fields inside this device shows that it can be halved by a vertical electrically-conductive wall across a diagonal disposed orthogonally to the plane containing the feed point. This creates a half-cylindrical DRA that has the advantages of being half the size and weight of the original cylindrical DRA and generating a lower back lobe [O'KEEFE S.G., KINGSLEY, S.P. AND SAARIO S.: "Radiation patterns of half volume HEM mode dielectric resonator antennas", to be published in IEEE Transactions on Antennas and Propagation, January 2002]. Antennas with low back lobes are useful for many mobile communications applications.

A single $HEM_{11\delta}$ mode half-cylindrical DRA is shown in Figures 1 and 2. The DRA comprises a half-cylindrical dielectric resonator 1 disposed with one of its semicircular faces on a grounded substrate 2 and its rectangular face against a conductive backwall 3. Energy is transferred into and out of the dielectric resonator 1 by way of a probe feed 4 embedded therein. Many different feed mechanisms are possible as alternatives to the probe feed 4 shown in Figure 1.

A particularly preferred feed mechanism, described in the present applicant's co-pending UK patent application no 0116930.9, is shown in Figure 2, which shows a half-cylindrical resonator 1 disposed on a grounded substrate 2 and against an 'L'-shaped conductive backwall 3. The grounded substrate 2 is mounted on a dielectric substrate 5, e.g. a printed circuit board (PCB), and a slot 6 is cut through the grounded substrate 2 along the line of the conductive backwall 3 on the side where the dielectric resonator 1 is located. A microstrip transmission line 7 passes along the dielectric substrate 5 on the face remote from the grounded substrate 2 so as to pass under the slot 6, thereby forming a slot feed for transferring energy into and from the dielectric resonator 1.

$HEM_{11\delta}$ mode cylindrical and half-cylindrical DRAs have the direction of maximum radiation along the x-axis (see Figure 1) of the antenna. There is a null in the pattern along the y-axis. It is common practice in the design of arrays of antennas to dispose the elements such that the nulls face each other so as to minimise the coupling between the elements. This practice simplifies the design of the array and so an array of $HEM_{11\delta}$ mode half-cylindrical DRAs might be expected to appear as in Figure 3.

The same arguments apply to an arrangement of $TE_{01\delta}$ mode quarter-split cylindrical DRAs which have a similar gain pattern to the HEM mode half-cylindrical antennas and which also have a conducting back plane or backwall. Quarter-split DRAs have the further advantage of being very wide bandwidth devices, when wide band operation is desirable. This applies also to any other arrangement and/or resonant mode of DRAs exhibiting nulls in their radiation patterns that enables them to be spaced adjacently with minimal mutual coupling.

However, there has been no investigation to date as to the arrangement possibilities of separate transmit and receive DRA elements.

According to a first aspect of the present invention, there is provided an antenna device comprising a pair of dielectric resonator antenna elements, each element comprising a dielectric resonator provided with a feed and a conductive backwall, wherein one element is configured as a transmit antenna and the other as a receive antenna, and wherein the elements are disposed such that the conductive backwalls directly face each other in a substantially parallel configuration.

Where the DRA elements have monopole feeds, they need to be disposed on or close to a grounded substrate. Where dipole feeds are used, a grounded substrate is not required. The conductive backwall of each element may touch the element or merely be disposed adjacent thereto without full contact (this can help to improve bandwidth). The DRA elements are preferably configured to have, in operation, radiation patterns with nulls or much reduced field strength in azimuth directions

substantially parallel to the backwalls. An array of pairs of DRA elements can then be constructed such that the nulls of one pair coincide with the nulls of neighbouring pairs, thus reducing electromagnetic coupling between the pairs. Furthermore, the conductive backwalls help to reduce possible radiation backlobes and thereby reduce coupling between the DRA elements of each pair.

The array may comprise a single pair of transmit and receive antennas, or may comprise two pairs of transmit and receive antennas mounted side by side on a grounded substrate.

As a further development, an array of pairs of DRA elements may be constructed as outlined above, the array extending indefinitely in one, two or three dimensions. It is particularly preferred that alternate pairs of transmit and receive antennas are mutually reversed so as to reduce electromagnetic coupling between diagonally-opposed elements. It is to be appreciated that this arrangement applies not only to an array of DRAs which are in some way operatively connected (e.g. all being fed with the same signal), but also to an array comprising several sub-arrays, each sub-array being a separate transmit/receive device potentially being fed with a separate signal or signals.

For example, a pico-base station may have a transmitting element at one end and a receiving element at the other, facing in an opposite direction. When two or more pico-base stations are used together, as is currently envisaged, they are advantageously disposed facing in alternate directions, i.e. with the transmitting elements and the receiving elements of adjacent pico-base stations being reversed. Such groups of separate base stations have a similar geometry to the single arrays also described in the present application.

According to a second aspect of the present invention, there is provided an antenna device comprising a two-by-two array of dielectric resonator antenna elements, each element comprising a dielectric resonator provided with a feed and a conductive

backwall, wherein two elements are configured as transmit antennas and two as receive antennas, wherein the elements are disposed such that the two transmit antennas and the two receive antennas are respectively arranged back-to-back with the conductive backwalls directly facing each other in a substantially parallel configuration.

Preferably, side-wise adjacent transmit and receive antennas of the array are arranged such that their conductive backwalls are co-linearly disposed. The two-by-two array may be extended indefinitely in one, two or three dimensions.

Embodiments of the present invention achieve what has hitherto been considered to be impossible, namely an omnidirectional transmit and receive antenna array with closely-spaced antenna elements having negligible or near-negligible electromagnetic coupling.

In currently preferred embodiments of the present invention, the dielectric antenna elements may be half-cylindrical DRAs operating in the $HEM_{11\delta}$ mode, with their rectangular surfaces disposed against or close to their associated conductive backwalls, or may be quarter-split cylindrical DRAs operating in the $TE_{01\delta}$ mode each with one rectangular surface disposed against or close to their associated conductive backwalls. Both of these DRA configurations exhibit a desired property of having nulls or near-nulls at 180° to each other.

Alternative DRA configurations exhibiting nulls or near-nulls in their radiation patterns that allow them to be located adjacently such that the nulls or near-nulls are aligned, thereby reducing electromagnetic coupling, may also be employed.

For example, a DRA can be made to have nulls at ±120° in azimuth from the main lobe rather than at ±90°, thereby allowing a triangular array of DRA elements to be constructed with adjacent DRA elements having aligned nulls or near-nulls. One way of achieving this result is to provide a DRA element as hereinbefore described

with a conductive backwall in the form of a box structure. Alternatively, the same result may be achieved by providing a planar conductive backwall having a lid or planar cross-member which covers the DRA element near or at the top of the backwall.

In a further example, it is possible to construct a DRA element having a radiation pattern with nulls or near nulls at ±135° in azimuth from the main lobe, which allows a square or rectangular array of DRA elements to be constructed with each DRA element radiating generally diagonally from the corners of the array, but with adjacent DRA elements (both side-wise adjacent and back-to-back adjacent) being arranged with their nulls or near-nulls in alignment.

Accordingly, a third aspect of the present invention provides an antenna device comprising an array of dielectric resonator antenna elements, each element comprising a dielectric resonator provided with a feed, wherein each element in operation has a radiation pattern with two nulls or near nulls in azimuth and a main lobe, the nulls being located at positions other than ±90° from a direction of the main lobe, and the elements being arranged in the array such that the main lobes are directed away from each other and such that the nulls or near nulls of adjacent elements are aligned with each other so as to reduce mutual coupling between adjacent elements.

In one embodiment, the elements are constructed such that the nulls or near nulls are located at ±120° in azimuth from the main lobe, as described above.

In an alternative embodiment, the elements are constructed such that the nulls or near nulls are located at ±135° in azimuth from the main lobe, as described above.

It will be appreciated that other configurations having nulls or near nulls in alternative azimuth positions may be used where appropriate.

An important precursor to the present invention is the discovery by the applicant that the near-field/far-field boundary of a DRA is very close to the surface of the dielectric resonator. This means that nulls in the far-field pattern are real and can dramatically reduce electromagnetic coupling between DRAs that are only a few centimetres apart. Hitherto, antenna elements in an antenna array have normally been spaced approximately half a wavelength apart, but the present applicant's discovery above means that an array of DRAs can have the elements spaced much closed than this without appreciable coupling. By arranging two half-mode DRAs back-to-back in accordance with the present invention, coupling between the two can be much reduced while allowing radiation into the other azimuth half-space, thereby achieving a near omnidirectional radiation pattern.

The resonance modes hereinbefore described have vertical polarisations, which is desirable for mobile telecommunications base stations, although horizontal polarisations may be achieved where desired. One way of achieving a horizontal polarisation is simply to turn the whole DRA and grounded substrate so that they lie in a vertical rather than a horizontal orientation with respect to a predetermined operating plane (which may be perpendicular to a direction of action of terrestrial gravity). An alternative way of achieving horizontal polarisation is to create a resonance mode that is intrinsically horizontally polarised, for example the TE mode in a cylindrical DRA or the EH mode for a half-split vertical cylinder.

Furthermore, by employing wide and low conductive backwalls, the antenna array as a whole may be constructed with a low profile with the additional advantages of improved efficiency and low backlobes.

In order further to reduce coupling between DRA elements, especially between transmit antenna elements and receive antenna elements (coupling between two transmit antenna elements or between two receive antenna elements is less of a problem, although also alleviated hereby), additional conductive divider walls may

be located between the elements. The divider walls are preferably located generally symmetrically between the elements in a cross-wise manner. Such divider walls may provide additional structural stability or rigidity to a radome or the like enclosing the antenna array. In embodiments of the present invention mounted in outdoor conditions, such as on the top of a telephone box or kiosk, a radome with such additional stability or rigidity can help to protect the antenna array from physical stress.

Where additional isolation between DRA elements is required, the dividing walls described above may be replaced by pairs of conductive dividing walls having radio wave absorbing material disposed therebetween may be provided in a similar fashion.

Alternatively, instead of providing conductive dividing walls, the antenna gain and the shape of the radiation pattern may be improved by cutting or otherwise providing slots in the grounded substrate (where provided) such that side-wise adjacent DRA elements are separated by the slots. The slots in the grounded substrate physically separate the grounded substrate into electrically isolated components in such a way that each of the side-wise adjacent DRA elements is provided with its own grounded substrate that is electrically isolated from the grounded substrate of the other side-wise adjacent DRA elements. This embodiment has a somewhat less omnidirectional radiation pattern overall than the embodiment above where dividing walls are used, but finds utility where a substantially uniformly omnidirectional radiation pattern is not required.

Alternatively, in a two-by-two array, a conductive box having four vertical conductive walls may be located between the back-to-back DRA elements such that the conductive box forms the conductive backwall for each element. Further shielding may be achieved by providing conductive extension walls or "ears" which project substantially perpendicularly from substantially the centre of each side of the box, thus separating side-wise adjacent elements and providing additional shielding between back-to-back elements. In a two-by-*n* array, where n is greater than 2, the

box may be extended along the length of the array, with optional conductive extension walls or "ears" being provided between side-wise adjacent elements on the longer walls of the box, with the shorter walls having extension walls or "ears" as before. The box may also have an optional conductive lid, which may give an improvement to the front-to-back ratio.

The present applicant has also determined that it is possible to excite a DRA over a wide range of impedances. This means that each of a pair of transmit and receive antennas may, for example, be fed by a 100Ω microstrip or strip line (or other appropriate feed mechanism) and may then be combined directly to give a 50Ω output. This avoids the need for impedance transforming sections of line and the associated size and mismatch losses. It is to be appreciated that impedance transforming line sections are also limited in bandwidth, as they are usually a quarter wavelength long and must be set up or configured for a particular frequency, which can reduce the bandwidth of an otherwise wide band DRA.

For a better understanding of the present invention and to show how it may be carried into effect, reference shall now be made by way of example to the accompanying drawings, in which:

FIGURE 1 shows a plan view of a prior art probe-fed half cylindrical DRA;

FIGURE 2 shows a vertical cross-section through a slot–fed half cylindrical DRA;

FIGURE 3 shows a one dimensional array of half cylindrical DRAs;

FIGURE 4 shows a two-by-two array of half cylindrical DRAs configured according to the second aspect of the present invention;

FIGURE 5 shows a two-by-two array of half cylindrical DRAs configured according to the preferred first aspect of the present invention;

FIGURE 6 shows a two-by-two array of half cylindrical DRAs provided with conductive dividing walls;

FIGURE 7 shows a two-by-two array of half cylindrical DRAs provided with pairs of conductive dividing walls inter-filled with metallic radio wave absorbing material;

FIGURE 8 shows a two-by-two array of half cylindrical DRAs provided with a conductive box backplane with optional extensions or "ears";

FIGURE 9 shows an array of separate DRA devices of the first aspect of the present invention disposed adjacently in alternate orientations;

FIGURE 10 shows a DRA element adapted to have a radiation pattern with nulls at ±135° in azimuth from a main lobe;

FIGURE 11 shows the radiation pattern of the DRA element of Figure 10; and

FIGURE 12 shows a radiation pattern for a DRA adapted to have nulls or near nulls at ±120° in azimuth from a main lobe.

Figures 1, 2 and 3 have already been discussed in the introduction to the present application.

Figure 4 is a plan view of a two-by-two array of half-mode DRAs each comprising a dielectric resonator element 1, 1' provided with a conductive backwall 3, the resonator elements 1, 1' all being disposed on a grounded substrate 2 and being fed by an appropriate feed mechanism (not shown). The feed mechanisms are configured such that elements 1 act as transmit antennas and elements 1' act as receive antennas. It can be seen that the two transmit elements 1 are disposed in a back-to-back configuration, as are the two receive elements 1', such that their respective backwalls

3 directly face each other in a substantially parallel configuration. This embodiment of the second aspect of the present invention gives near-omnidirectional coverage, but there is still weak coupling between diagonally opposed transmit 1 and receive 1' elements.

A significant improvement is achieved by modifying the configuration of the elements 1, 1' in accordance with the first aspect of the present invention and as shown in Figure 5. As in Figure 4, the elements 1, 1' are arranged on a grounded substrate 2 so that both a transmit 1 and a receive 1' element can radiate in directions towards the top and the bottom of the page. However, the elements 1, 1' are arranged such that the back-to-back pairs each comprise one transmit 1 and one receive 1' element, rather than two of the same, and the two pairs are arranged in a mutually reversed configuration. By arranging the elements 1, 1' in this way, it is possible significantly to reduce coupling between transmit 1 and receive 1' elements while still achieving a near-omnidirectional pattern. Furthermore, weak coupling along the diagonal between transmit 1 and receive 1' elements is much less of a problem than coupling between two transmit elements 1 or between two receive elements 1' (as in Figure 4).

Although the conductive backwalls 3 help to reduce radiation backlobes to a significant extent, there may still be some leakage around the edges of the backwalls 3. In order to address this and to provide improved isolation and reduced coupling between the elements 1, 1', conductive (e.g. metal) dividing walls 8 may be located between the elements 1, 1' and contacting the grounded substrate 2 as shown in Figure 6. The conductive dividing walls 8 are preferably substantially equidistant between the elements 1, 1', with one wall substantially parallel to the backwalls 3 and the other substantially perpendicular thereto. The dividing walls 8 shown in this example are of the same height as the elements 1, 1', but may have any appropriate height, which may be less than or greater than the height of the elements 1, 1'.

To reduce coupling between the elements 1, 1' even further, the conductive dividing walls 8 of Figure 6 may be replaced by double dividing walls 9 inter-filled with a radio wave absorbing material 10 (e.g. a metal) as shown in Figure 7.

Figure 8 shows a further possibility for reducing coupling between elements 1, 1'. Here, a conductive rectangular box 11 is located between the elements 1, 1', with two opposed sides 12 of the box 11 serving as the conductive backwalls for the elements 1, 1'. The box 11 is preferably at least as tall as the elements 1, 1', and may be made out of a metal. In order to reduce coupling between adjacent elements 1, 1' even further, optional extension walls or "ears" 13 may be provided which extend substantially perpendicularly from central regions of the sides of the box 11. The box 11 may be provided with an optional conductive lid (not shown) which can help to improve a front-to-back ratio of the radiation pattern.

Figure 9 shows part of a one dimensional array of separate transmit/receive devices 14, each comprising a transmit element 1 and a receive element 1' arranged back-to-back on a separate grounded substrate 2, the elements 1, 1' of each device 14 being provided with conductive backwalls 3 and an appropriate feed mechanism (not shown) as before. The array of separate devices 14 may be extended indefinitely, and also in two or three dimensions, so as to form, for example, a compound pico-base station. Alternate neighbouring devices 14 have their transmit 1 and receive 1' elements mutually reversed so as to reduce coupling between diagonally adjacent transmit 1 and receive 1' elements. It will be appreciated that this applies also to an array (in one, two or three dimensions) of elements 1, 1' disposed on a single grounded substrate 2 and sharing a feed signal. As before, conductive dividing walls or the like may be provided for additional shielding.

Figure 10 shows a dielectric resonator antenna element 20 comprising a quarter cylindrical dielectric resonator 21 disposed with one of its rectangular surfaces on a fan-shaped grounded substrate 22 and its other rectangular surface abutting a conductive backwall 23. A conductive "lid" or cover 24 extends from the conductive

backwall 23 over the dielectric resonator 21, and a feed (not shown) is provided for transferring energy into and out of the dielectric resonator 21.

In operation, the DRA element 20 of Figure 10 has an azimuth radiation pattern as shown in Figure 11, having a main lobe 25 and two nulls or near nulls 26, 26' located at ±135° in azimuth from the main lobe 25.

Four DRA elements 20 may therefore be formed into a square array, with the main lobes 25 being aligned in an azimuth plane but pointing away from the array with each main lobe 25 being directed along a diagonal of the square array and the nulls or near nulls 26, 26' of adjacent elements 20 being aligned so as to reduce mutual coupling.

Figure 12 shows an azimuth radiation pattern having a main lobe 30 and two nulls or near nulls 31, 31' located at ±120° in azimuth from the main lobe 30. This pattern is generated by a DRA element having a half cylindrical dielectric resonator mounted against a conductive backwall as described above, but with the conductive backwall being formed as a box structure. Accordingly, three such DRA elements may be formed into a triangular array, with the main lobes 30 being aligned in an azimuth plane but pointing away from the array with each main lobe 30 being directed along apex directions of the triangular array and the nulls or near nulls 31, 31' of adjacent elements being aligned so as to reduce mutual coupling.

CLAIMS:

1. An antenna device comprising a pair of dielectric resonator antenna elements, each element comprising a dielectric resonator provided with a feed and a conductive backwall, wherein one element is configured as a transmit antenna and the other as a receive antenna, and wherein the elements are disposed such that the conductive backwalls directly face each other in a substantially parallel configuration.

2. A device as claimed in claim 1, wherein the feeds comprise monopole feeds and wherein the elements are disposed on a grounded substrate.

3. A device as claimed in claim 2, wherein the feeds comprise slot feeds adjacent the conductive walls.

4. A device as claimed in claim 1, wherein the feeds comprise dipole feeds.

5. An array of antenna devices as claimed in any preceding claim, wherein the elements are adapted, in use, to have radiation patterns exhibiting nulls or near nulls in azimuth directions substantially parallel to the conductive backwalls, wherein sidewise adjacent members of the array are mutually disposed such that the directions of the nulls or near-nulls in the radiation patterns of their elements coincide with each other, and wherein an orientation of the transmit and receive antenna elements alternates between adjacent devices.

6. An array as claimed in claim 5, wherein each antenna device is a separate device with a separate feed signal.

7. An array as claimed in claim 5, wherein the antenna devices share a feed signal.

8. An antenna device comprising a two-by-two array of dielectric resonator antenna elements, each element comprising a dielectric resonator provided with a feed and a conductive backwall, wherein two elements are configured as transmit antennas and two as receive antennas, wherein the elements are disposed such that the two transmit antennas and the two receive antennas are respectively arranged back-to-back with the conductive backwalls directly facing each other in a substantially parallel configuration.

9. A device as claimed in any preceding claim, wherein conductive divider walls are provided between the elements so as to reduce electromagnetic coupling therebetween.

10. A device as claimed in claim 9, wherein the conductive divider walls are located generally symmetrically between the elements in a cross-wise manner.

11. A device as claimed in claim 9 or 10, wherein the conductive divider walls each comprise a pair of conductive walls with a radio wave absorbing material sandwiched therebetween.

12. A device as claimed in any one of claims 1 to 8, wherein the conductive backwalls of the elements are joined together to form a conductive box-shaped structure.

13. A device as claimed in claim 12, wherein the conductive box-shaped structure is further provided with conductive extension walls which project substantially perpendicularly therefrom between side-wise adjacent elements.

14. An antenna device comprising an array of dielectric resonator antenna elements, each element comprising a dielectric resonator provided with a feed, wherein each element in operation has a radiation pattern with two nulls or near nulls in azimuth and a main lobe, the nulls being located at positions other than ±90° from

a direction of the main lobe, and the elements being arranged in the array such that the main lobes are directed away from each other and such that the nulls or near nulls of adjacent elements are aligned with each other so as to reduce mutual coupling between adjacent elements.

15. A device as claimed in claim 14, wherein the elements are constructed such that the nulls or near nulls are located at ±120° in azimuth from the main lobe.

16. A device as claimed in claim 14, wherein the elements are constructed such that the nulls or near nulls are located at ±135° in azimuth from the main lobe.

17. An antenna device substantially as hereinbefore described with reference to Figures 4 to 12 of the accompanying drawings.

Application No:	GB 0205739.6	**Examiner:**	Dr E.P. Plummer
Claims searched:	all	**Date of search:**	13 December 2002

19

Patents Act 1977 : Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
A	-	WO01/69721A1 Antenova & University of Sheffield

Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC^{T}:

Worldwide search of patent documents classified in the following areas of the IPC^{7}:

H01Q

The following online and other databases have been used in the preparation of this search report:

Online: WPI, PAJ, EPODOC, INSPEC